OPTOMIZATION OF TIME_VARYING OUTPATIENT DEPARTMENT TRAFFIC

A. F. Abdel Gawad[1,] M. S. Aly[2], A.S. A Mohamed [2].

[1] Police hospital, Cairo, Egypt

[2]Department of systems and biomedical engineering, Cairo university, Egypt

Abstract – **The development of existing healthcare systems and medical equipment are constrained with the architectural design of the old hospitals. One of these constraints is imposed on the traffic of outpatient visitors to a specific clinic and among other clinics.**

The present study focuses on Om El-Masrien hospital in Giza governorate, Egypt built in 19--. This study deals with the time-varying number of visitors to outpatient departments and is based on a collected data set collected along two years.

The output results from the study improves the traffic to outpatient department by reallocating the clinics and reducing the cost of the current situation to 54.2%

Keyword:**Outpatient traffic, Assignment problem, optimization.**

I. INTRODUCTION

The impact of technological developments propagates in all fields of our daily life. One of these fields is healthcare delivery systems (HCDS), and mainly hospitals. The developments can be seen from the starting instant of building these HCDS's and continuing with their operation. This is the state of new constructed HCDS's, but the main problem concerns with old one where the architecture needs to be modified to cope with the new developed medical services and equipment.

Outpatient department in a hospital is viewed by patients as the gateway to the hospital [1]. The process of obtaining an efficient assignment can be considered as a mathematical optimization problem, where single or multiple objective functions are to be minimized and necessary constraints satisfied [2]. Optimization of hospital internal traffic deals with allocating different clinics at certain locations so that patient total traffic is minimized, and therefore receiving of medical services provided. On the other hand, optimization of internal traffic in existing hospital faces many constraints due to incapability of changing locations of some clinics that require special site preparation as dental clinic for example. So, optimal solution would be achieved subjected to the hospital present constraints.

The present study focuses on a governmental public hospital represented by Om El-Masrien Hospital built in 19-- as case study due to the massive flow rate to its outpatient department clinics and hence the importance of traffic minimization can be clearly shown and applied.

To optimize the traffic, we applied the famous assignment problem formulation to the outpatient traffic in the case study hospital [3,4,5]. The cost is represented as Cij where i,j are source and destination [3,6]. In the clinic assignment problem, only one room can be assigned for a single clinic, and vice versa as shown in Table I.

The assignment problem in which (n) clinics are assigned to (n) rooms can be formulated as follows : Let C_{ij} be cost of assigning clinic (i) to room (j) and define :

a. Decision Variables

$$X_{ij} = \begin{cases} 1, & \text{if Clinic (i) is assigned to room (j)} \\ 0, & \text{otherwise} \end{cases} \quad ..(1)$$

Then, the assignment problem formulation is as follows :

b. Objective Function

$$\text{Minimize} \quad Z = \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} X_{ij} \quad ..(2)$$

Subject to :

c. Structural Constraints

$$\sum_{i=1}^{n} X_{ij} = 1, \quad j = 1, 2, \ldots, n \quad ..(3)$$

$$\sum_{j=1}^{n} X_{ij} = 1, \quad i = 1, 2, \ldots, n \quad ..(4)$$

$$X_{ij} = \text{binary variable}$$

Where Z is the over all cost which is the overall (path-length)*(number of clinic visitors) for all clinics and all rooms. The path length is function of the distance traveled from the gate entrance to a clinic by a patient.

If we assume the patient travels in the system with a constant speed, then minimizing Z means that we are minimizing the time consumed to get the medical service (i.e. we are maximizing patient comfort) , and minimizing the consumption of the hospital passages and buildings. On other words, the hospital is more productive and economic.

II. METHOD

Data Required

Data required for the optimization process are divided into two categories. The first category is the available rooms distances separating them from the ouptatient department enterance and can be obtained from the hospital general layout. These distances and the different clinics codes, used for simplification, are presented in table II. Also, the current assigned clinic for each room is provided.

The second category represents the number of patients seeking the medical services. Data from Om El-Masrien hospital medical records are collected and represented in table-III. The hospital is a multi-building hospital, and each building is a multi-story building.

Minimization Technique

The problem of patient traffic minimization in the outpatient department is solved by using a ready-made software that is a component of Microsoft Excell called Solver, and by applying it to the previous assignment problem formulation with further specific appended constraints for the case study hospital.

III. RESULTS

The solution and suggestion for the present problem depend on the collected data of the selected hospital along two years 2002 & 2003. Just for illustration, the minimization of outpatient traffic for a certain month is as follows :

A) Traffic improvement :

Solving the current problem with the collected data reveals the current cost and is intended to find both the optimum as well as the worst solutions. Table IV shows the current cost, the optimum cost, and the percentage improvement.

B) Clinic reassignment :

To realize the objective of this study, new location of the available clinics is deduced taking into consideration the constraints mentioned before. Table V shows current, optimum, and worst clinic assignment for the same certain month.

Note, the room codes consists of three digits and will be as follows : Left digit [Floor (F -> first, S -> second, T -> third)], middle digit [Building (A -> right, B-> front, C->left)], right digit [Room No.]

A performance scale can be constructed by considering the maximum cost as the 0% of the scale (i.e. worst cost), and the minimum cost as the 100% of the scale (i.e. best cost). The current formulation has the gate entrance as a source, while the rooms which include the clinical activities as destination. In this case, the patient travels from the hospital entrance to the desired clinic and to the gate after receiving the service. In fact, this formulation is a simplified version of a more general case where a patient travels from the gate to the requested clinic which in turn refers him to another clinic before his departure of the outpatient area to the hospital gate.

To obtain the maximum/minimum cost, we have to set the optimization criteria of the objective function in the considered formulation to max/min.

The efficiency of a certain assignment can be obtained by the following equation :

$$\text{Current evaluation percent of the outpatient department (efficiency)} = \frac{Worst - Current}{Worst - Best} \quad ..(5)$$

The maximum cost, minimum cost, current cost, and current evaluation percentage were computed for each month of the 24-months time series. Figure 1 illustrates the former three variables, while the curve of the last variable is illustrated in Fig. 2. Also, some statistics of the last variable is listed in the first column in table VI. A managerial action can be performed to improve the traffic flow efficiency percentage in the outpatient area. This action represents the reassignment of clinics to rooms every a fixed period instead of only one assignment at the beginning. Two practical values for the fixed period are considered 6 months and 1 year. To clarify the managerial action, let us consider the case when the fixed value is 1 year as an example. In this example, the original assignment is considered during the first 12 months (i.e. 1-12), while the assignment for the next 12 months (i.e. 13-24) is the assignment associated with the solution of the minimum cost of month 12. Hence, the current cost curve is computed by considering two assignments instead of a single assignment. The efficiency percentage curve can be calculated for the period of study (i.e. 24 months) and curve statistics can be computed. Table VI shows the current evaluation (i.e. efficiency) statistics for the original case without any managerial action, the second case with a managerial action every year, and the third case with a managerial action every 6 month.

IV. CONCLUSION

This study was designed to reach the optimum assignment of rooms to clinics of the outpatient department clinics of a public hospital of Om El-Masrien Hospital in Giza as the case study hospital..

A number of constraints were applied regarding a running hospital like infra-structure requirements of some clinics as dental clinic and also the health status of the patients seeking the medical services as in physiotherapy clinic. Any other constraints can be easily applied according to demands of hospital under study with minor modifications to this study.

The results showed a reduction of the effort exerted by patients seeking the medical services provided by the outpatient department can be achieved. The reduction was about 50% of the current cost.

Also, study provided a performance scale for evaluating the efficiency. The efficiency was found to be about 26%. while the guided managerial action can improve the efficiency to about 81% in our example. The scale can be applied to any given hospital to evaluate the current efficiency of its outpatient department assignment using limited calculations and an available software.

REFERENCES

1. Larry J. Shuman, R. Dixon Speas Jr., John P. Young, "Operations Research in Health Care", Johns Hopkins University Press, p.226 : 309, 1975.

2. Hojjat Adeli, "Advances in Design Optimization", Chapman & Hall., London, p.266 : 299, 1994.

3. Hamdy A. Taha, "Operations Research, An Introduction", Prentice-Hall, p.194 : 516, 1997.

4. Alan H. Kvanli, Robert J. Pavur and C. Stephen Gugnes, "Introduction to Business Statistics, A Computer Integrated Data Analysis Approach", Dane Shaut, p. 609 : 660, 2000.

5. Frederick S. Hillier, Gerald J. Lieberman, "Introduction to Operations Research", 4th edn., McGraw-Hill, p.682 : 695, 1989.

6. E. Paul DeGarmo, William G. Sullivan, John R. Canada, "Engineering Economy", 7th edn., Collier MacMillan Publishers, p.547 : 552, 1984.

TABLE I
The assignment model with (n) clinics and (n) rooms.

		Locations(rooms)			
		1	2	..	N
Clinics	1	C_{11}	C_{12}	..	C_{1n}
	2	C_{21}	C_{22}	..	C_{2n}
	..	..	..	..	..
	..	..	..	..	..
	n	C_{n1}	C_{n2}	..	C_{nn}

TABLE II
Clinics, clinics codes, and distances from each room to the outpatient department main entrance

Room	Clinic Name	Clinic Code	Distance from the entrance (m)
1	Pediatric clinic	PED	41.5
2	Ear-Nose-Throat clinic	ENT	82
3	Gynecology clinic	GYN	68
4	Physio-therapy clinic	PHY-THR	13
5	Orthopedic clinic	ORTH	23.5
6	Psychiatric clinic	PSY	31
7	Urology clinic	URO	14
8	Internal Medicine clinic	INT	87
9	Diabetes clinic	DIAB	82
10	Dermatology clinic	DERM	95
11	Surgery clinic	SURG	76

Table III
Outpatient distribution for different clinics during 2002-2003

	Ped	ENT	Gyn	Phy-Thr	Orth	Psy	Uro	Int. Med	Diab	Derm	Surg
Jan-02	1278	2050	796	1130	2440	1389	509	6706	1778	1151	1041
Feb-02	762	1455	594	779	2006	1115	368	4931	1586	842	835
Mars-02	1904	2411	800	1208	3283	1471	537	8083	2024	1227	1057
April-02	1944	2153	843	1049	3118	1361	488	7629	1820	1228	1020
May-02	1149	1796	735	929	2874	1256	484	7075	1691	1078	1018
June-02	1199	1847	773	1103	3236	1431	515	8048	1615	1276	1330
July-02	1098	1876	745	1043	3424	1309	510	9306	1838	1847	1405
Aug-02	1171	1693	868	1068	2841	1263	573	9425	1974	1772	1527
Sept-02	1190	1786	761	1063	2713	1229	555	8407	2040	1313	1274
Oct-02	1159	1889	890	1076	2706	1431	516	7815	2499	1166	1322
Nov-02	971	1355	630	860	2167	1002	525	5760	2546	860	847
Dec-02	1084	1617	670	1070	2284	1206	484	6611	3012	825	902
Jan-03	1481	1686	730	1048	2351	1294	512	7981	3330	968	956
Feb-03	703	1370	632	986	1904	938	392	5428	2704	772	689
Mars-03	1113	1683	852	1187	2691	1168	567	7598	3564	964	1003
April-03	1255	1667	886	1119	2529	1245	393	6623	3481	1125	1054
May-03	1262	1448	690	924	2684	983	505	7376	2336	1210	1049
June-03	1161	1582	809	952	3092	1013	555	7516	1794	1246	1259
July-03	1219	1908	517	948	3063	982	530	8737	1947	1575	1361
Aug-03	1114	1760	540	853	3038	951	612	8421	1947	1377	1407
Sept-03	994	1569	539	900	2944	1033	613	9017	2073	1189	1360
Oct-03	1622	1622	502	781	2519	946	561	9887	2076	1009	1163
Nov-03	1055	1398	367	612	2091	769	446	7349	1791	765	762
Dec-03	893	1600	492	972	2574	1084	566	10324	1920	960	1061

Table IV
Optimized and current clinic allocations costs and percentage improvement for a certain month.

Clinics allocation	Cost	Comparison with current case	Comparison with worst case
Best	**1098853**	**% 54.2**	**% 48.54**
Current	**2028140**	**% 100**	**% 89.6**
Worst	**2263844**	**% 111.6**	**% 100**

Table V
Clinics current, optimum, and worst room allocation.

Clinics	Current Location	Optimum location	Worst Location
Pediatric	FB1	FC2	SA2
Ear-Nose-Throat clinic	SA2	SC1	SB1
Gynecology	SB1	SA3	FC2
Physio-therapy	FA1	FB1	FA2
Orthopedic	FA2	FA2	SA3
Psychiatric	FC2	TC1	FA1
Urology	FC1	SA1	FC1
Internal Medicine	SA1	FA1	TC1
Diabetes	SA3	FC1	SA1
Dermatology	TC1	SA2	FB1
Surgery	SC1	SB1	SC1

Table VI
Current evaluation percentage statistics for a period of 24 months

	Original case	1 year case	6month case
Max	0.319	1.000	1.000
Min	0.212	0.212	0.275
Mean	0.259	0.630	0.813
Std.Dev.	0.026	0.369	0.306

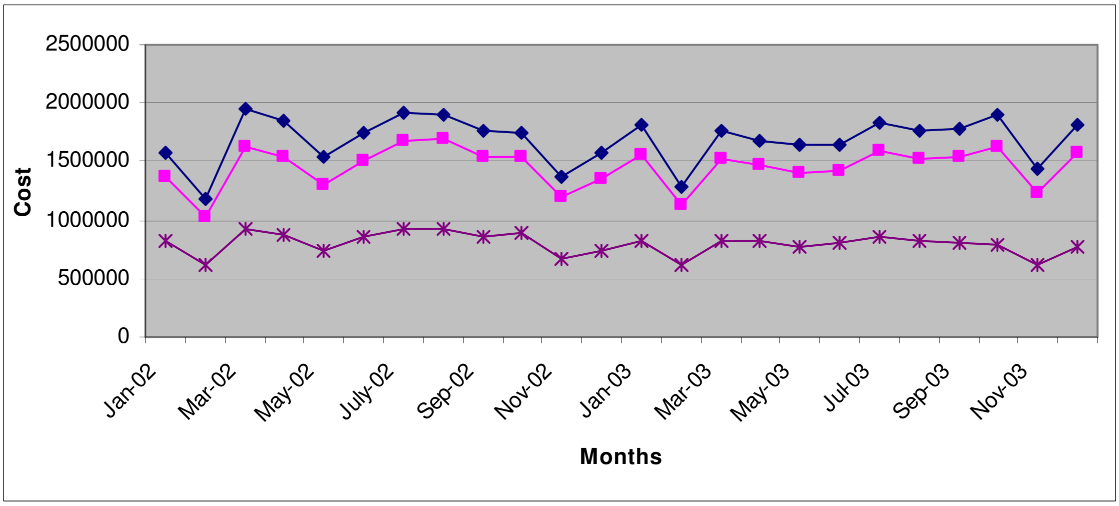

Figure 1 Worst cost (upper curve), current cost (middle curve), and minimum cost (lower curve)

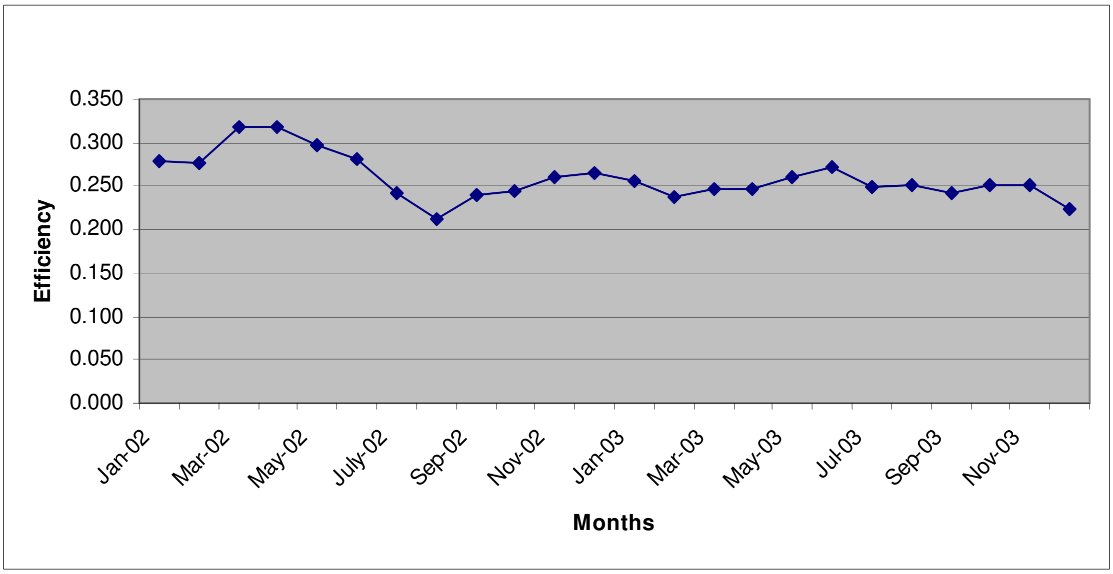

Figure 2 Efficiency curve of the current situation